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OPERATIONAL DYNAMICS

M.V. ARCTIC

SPRING 1986 PERFORMANCE TRIALS

VOYAGE REPORT

Prepared for
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17. Abstract

This report describes the first inward voyage to Nanisivik in early June, 1986 made by the M.V. Arctic following her upgrading in shell strength and the fitting of a new bow. The open water and ice trials conducted during the voyage are described and the main findings are provided which confirmed the improved performance capabilities predicted by the model tests of the new bow.

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17. Résumé

Ce rapport décrit le premier voyage à destination de Nanisivik, effectué au début de juin 1986 par le N.M. Arctic à l'issue des travaux visant à relever la résistance de sa coque et à l'équiper d'une nouvelle proue. Les essais faits en eau libre et en eaux chargées de glaces durant le périple y sont décrits ainsi que les principals conclusions qui confirment l'amélioration des performances prévue par les essais sur maquette équipée de cette proue.

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SUMMARY

1. Introduction

This report describes the first inward voyage to Nanisivik made in early June 1986 by the M.V. Arctic following her upgrading in shell strength and the fitting of a new bow of improved icebreaking design. The open water and ice trials conducted during the voyage confirmed the improved performance predicted by the model tests of the new bow.

2. Overall Voyage

The voyage from Montreal to Nanisivik, including the trials program, was completed in 15½ days. The whole passage, including docking at Nanisivik, was conducted successfully by the M.V. Arctic without assistance.

3. Open Water Trials

The open water trials were conducted in the St. Lawrence in the vicinity of Les Escoumins and Bic Island. They confirmed that the full power speed achieved is slightly greater than with the old bow as was predicted by the model tests. These trials also confirmed that the vessel's open water manoeuvering qualities continue to be as good as with the old bow.

4. Ice Trials

The ice trials were conducted in Baffin Bay and Admiralty Inlet and confirmed that the M.V. Arctic can maintain continuous motion at full power in non-pressured ice up to about 1.6 metres in thickness. This corresponds to the most optimistic of the model test predictions.

The ramming capabilities of the ship were sufficient to overcome all the heavier ice conditions encountered on the voyage. There were, however, two occasions in which the vessel became stuck after ramming a ridge and was extracted only with great difficulty. This suggests that the power requirements (ahead and astern) for arctic vessels should give recognition to the icebreaking effectiveness of the bow. Throughout all the numerous ramming and backing operations conducted on these trials there was no evidence of exceedence of permissible hull stresses. Ice ingestion in the propeller, however, did produce many high excursions of torque and thrust.

The shear zone at the entrance to Admiralty Inlet proved to be the greatest ice-transiting obstacle of the voyage. The experience of this occasion suggests that a strategic plan for the best approach and crossing of the shear zone is required for the first entry voyage each year.

The manoeuvering trials demonstrated that the M.V. Arctic cannot achieve continuous turning under the action of the rudder alone in ice above about 1 metre in thickness. In thicker ice, sizeable course alterations have to be performed as a series of channel breakout manoeuvers always conducted in such a manner as to provide sufficient space for the stern to swing outwards. Continued efforts are required to perfect this channel breakout technique. To that end, the excellent temporary performance recording system used for these trials should be incorporated into the ship's permanent instrumentation system for onboard use in perfecting ramming and manoeuvering techniques as well as for other recording purposes.

The uniform ice conditions found throughout Admiralty Inlet and up to the dock provided an excellent proving ground for the M.V. Arctic and permitted over 200 tests to be recorded. On the other hand, the ice regime in Baffin Bay was found to be generally unsuited to the conduct of ice trials of this precise nature where a large expanse of smooth ice is required. The overall current and wind dynamics of Baffin Bay make this kind of ice difficult to find.

5. Recommendations

The following main recommendations arise from these trials,

- A further program of ice trials should be conducted at the end of the ship's arctic season to assess her effectiveness in an advanced winter growth ice regime subject to corresponding composition, strength and dynamic conditions.

- An investigation should be made to determine the relationship between icebreaking bow effectiveness and power requirements to reduce the present risk of long and high momentum vessels becoming stuck after a ram and being difficult to extract.

Supplementary recommendations related to investigations into the reasons for apparently increased ice ingestion into the propeller and into the potential for improving sternwards icebreaking and canting during manoeuvers.

SOMMAIRE

1. Introduction

Le rapport dont il est rendu compte ici décrit le premier périple à destination de Nanisivik effectué au début de juin 1986 par le N.M. Arctic à coque renforcée et équipé de sa nouvelle proue brise-glace destinée à améliorer les caractéristiques de déglaçage du navire. Les essais en eau libre et dans les eaux chargées de glace effectués durant le voyage ont confirmé les performances améliorées du navire, prédites par les essais sur maquette.

2. Comportement général

Le voyage de Montréal à Nanisivik s'est fait en 15 jours et demi, y compris les essais prévus. Tout s'est déroulé normalement, de même que la mise à quai à Nanisivik sans aide extérieure.

3. Essais en eau libre

Ils se sont déroulés dans le St-Laurent au large des Escoumins et de l'île du Bic. Comme prévu par les essais sur maquette, la vitesse à puissance maximale a été légèrement améliorée sans que le navire ne perde de sa souplesse de manoeuvre.

4. Essais dans les eaux chargées de glaces

Ces essais, qui se sont déroulés dans la baie de Baffin et dans l'inlet de l'Amirauté, ont confirmé l'aptitude de l'Arctic à avancer continûment à puissance maximale dans des glaces sans crêtes ayant jusqu'à 1,6 m d'épaisseur ce qui correspondait aux prévisions les plus optimistes des essais sur maquette.

Dans les marches alternées, le navire a réussi à vaincre tous les types de glaces rencontrées, sauf lorsque à deux reprises il s'est trouvé coincé dans une crête qu'il avait chargée et dont il n'a pu se dégager qu'avec beaucoup de difficulté. Ceci a amené les chercheurs à penser que les caractéristiques de vitesse en marche avant et arrière d'un navire de cote arctique devraient être reliées au type de proue brise-glace dont il est équipé et à l'efficacité de son action contre les glaces. Tout au long des essais dans les eaux chargées de glaces, les efforts exercés par celles-ci sur la coque n'ont jamais dépassé les valeurs de contrainte admissibles. Par contre, les heurts entre l'hélice et les glaces ont provoqué des fluctuations importantes dans le couple moteur et dans la poussée.

La plus grande difficulté rencontrée durant le voyage a été le franchissement de la zone des glaces cisaillantes qui bouche l'entrée de l'inlet de l'Amirauté. Ce fait souligne l'importance d'avoir à sa disposition au début de toute nouvelle saison une information suffisante permettant de décider de la meilleure approche à suivre pour aborder et franchir cette zone.

Les essais sur les qualités manoeuvrières de l'Arctic dans les glaces ont montré que celui-ci ne peut effectuer un changement de cap par l'action de la seule timonerie, dès que la glace dépasse un mètre d'épaisseur. Dans ce cas, tout changement de cap de quelque importance doit comporter une série de marches alternées visant à ouvrir des passages dans les glaces, tant à l'avant qu'à l'arrière. La mise au point de cette technique nécessitera toutefois une étude plus poussée. C'est pourquoi, il est suggéré que le système d'enregistrement installé à bord du navire à titre provisoire et qui a donné de si bons résultats, fasse partie intégrante de la chaîne de mesure et qu'il soit utilisé à fond, notamment pour perfectionner les manoeuvres dans les glaces et les techniques de charge.

Les glaces d'épaisseur uniforme rencontrées dans l'inlet de l'Amirauté et jusqu'à l'endroit où le navire a accosté ont fourni une belle occasion de mettre celui-ci à l'épreuve et ont permis d'effectuer plus de 200 essais enregistrés. Par contre, les conditions glacielles dans la baie de Baffin n'ont pas permis l'exécution de tels essais qui nécessitent un vaste espace recouvert de glaces sans aspérités; or, le régime de courant et de vent sont tels dans cette baie que cette condition se trouve rarement réalisée.

5. Recommandations

Les principales recommandations découlant des essais sont les suivantes:

- Effectuer d'autres essais dans les glaces, mais vers la fin de la saison de navigation, c'est-à-dire en période de début glaciel, afin d'évaluer les qualités manoeuvrières du navire en fonction de la composition, la résistance et l'action des glaces en formation.

- Faire une recherche sur la correspondance à établir entre les caractéristiques de vitesse d'un navire et l'efficacité de sa proue brise-glace, dans le but de réduire les risques qu'un navire de la masse, de la vitesse et de la longueur de l'Arctic se trouve coincé dans les glaces qu'il a chargées.

Le rapport formule d'autres recommandations sur la nécessité de poursuivre la recherche, notamment en vue de déterminer pourquoi les heurts entre l'hélice et les glaces se sont multipliés, de mieux étudier la possibilité de briser les glaces par la poupe et enfin d'améliorer l'aptitude du navire à effectuer des "mouvements de roulis" pour se dégager des glaces.

1. INTRODUCTION

This report describes the principal features of the first inward voyage to Nanisivik in early June, 1986 of the M.V. Arctic. The vessel underwent a major upgrading during the 1985/86 winter refit, an important component of which was the replacement of the original icebreaking bow with a new bow of improved design. Coupled with increased side shell strengthening, it was anticipated the the M.V. Arctic would undertake extended season voyages into the arctic with an early June entry into Zone 13.

The new bow was model tested in both open water and in ice conditions which indicated an improved level of performance. A primary purpose of this voyage was to conduct a series of tests to establish the ship's full-scale performance capabilities for comparison with the model scale predictions. The program of tests was successfully conducted in the St. Lawrence River, Baffin Bay and Admiralty Inlet. The principal findings arising therefrom, which confirmed the most optimistic of the model scale predictions, are contained in this report.

2. OVERALL VOYAGE DESCRIPTION

The M.V. Arctic 1986 Spring Performance Trials voyage commenced with departure from Section 50 Montreal docks on May 24, 1986 at 1100 hours (241100) and was completed on berthing at Nanisivik on June 8, 1986 at midnight (082400). The ship's route is shown in Figure 2.1.

There were three distinct sectors to the voyage which corresponded to the three sets of trials to be performed, as follows,

1. Open water trials in the vicinity of Les Escoumins.
2. Medium ice trials to be conducted in Baffin Bay.
3. Heavy ice trials to be conducted in Admiralty Inlet.

The voyage summary for these three sectors is provided in the following table.

Table 2.1 - Voyage Summary

SECTOR		PERIOD		HOURS		SEAMILES	
No	Locations	from	to	Passage	Trials	Passage	Trials
1.	dep. Montreal @50 dep. Bic Island	241100	252120	20.3	14.0	285	100
2.	dep. Bic Island arr. Admiralty Inlet	252120	041700	201.7	34.0	2471	82
3.	arr. Admiralty Inlet arr. Nanisivik Deck	041700	082400	96.0	7.0	60	2
Totals				318.0	55.0	2816	184
Grand Total				373.0		3000	

The ship's position at noon each day is provided in Table 2.2, together with daily distances and speeds.

The voyage of 2816 nautical miles was covered in 318 steaming hours for an average speed of 8.85 knots. In addition a further 184 nautical miles were steamed in 55 hours for the purpose of the trials program.

Figure 2.1 - Ship's Route

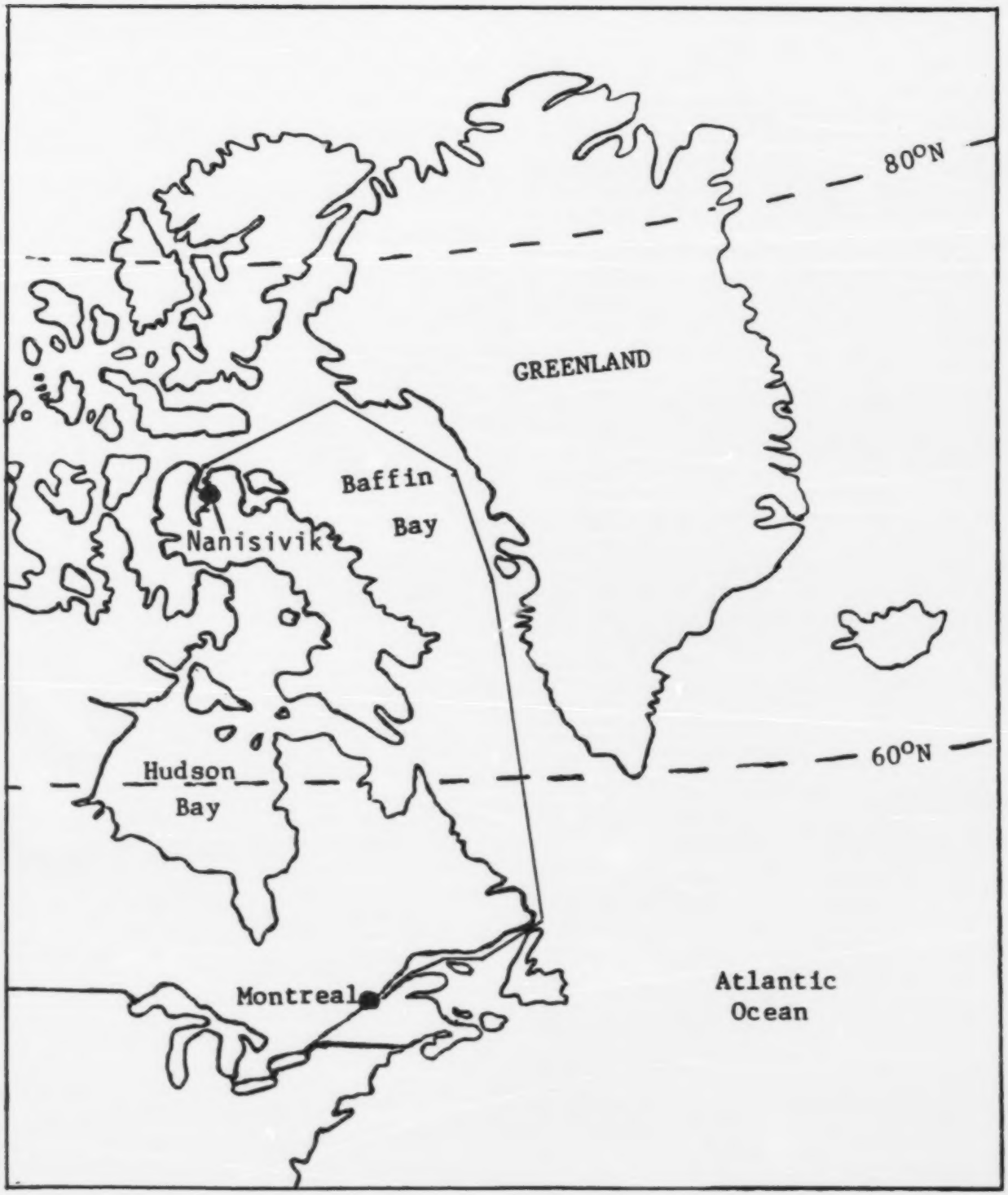


Table 2.2 - Noon Positions

Date	Noon Position		Noon to Noon	
	Latitude	Longitude	Distance seamiles	Speed knots
May 24, 1986	Montreal Harbour		} 285	Var
May 25, 1986	Off Les Escoumins			
May 26, 1986	49° 57'N	63° 14'W	221	15.03
May 27, 1986	52° 20'N	54° 57'W	378	15.75
May 28, 1986	56° 55'N	53° 29'W	314	14.27
May 29, 1986	63° 17'N	54° 17'W	383	15.96
May 30, 1986	68° 43'N	55° 17'W	327	13.63
May 31, 1986	73° 00'N	58° 00'W	269	11.24
June 01, 1986	74° 40'N	62° 04'W	134	13.18
June 02, 1986	74° 43'N	61° 48'W	-	-
June 03, 1986	76° 04'N	69° 14'W	130	6.84
June 04, 1986	74° 13'N	81° 52'W	225	9.38
June 05, 1986	73° 42'N	84° 45'W	75	3.61
June 06, 1986	73° 34'N	85° 05'W	36	1.63
June 07, 1986	73° 17'N	85° 24'W	15	0.63
June 08, 1986	73° 06'N	84° 30'W	20	0.83
	Nanisivik Dock		4	Var
Totals			2816	8.85

3. OPEN WATER TRIALS

The M.V. Arctic departed from Montreal on May 24, 1986 at 1100 hours (241100) and commenced ballasting on the passage down river. On arrival off Les Escoumin measured mile range on May 25, 1986 at 0500 hours (250500) ballasting was completed drafts, trim and heel were checked and adjusted to the trial requirements. During the down river passage a meeting was held between the trials team and ship's officers to explain the test program. The open water trials program was based on speed trials off Les Escoumins followed by manoeuvering trials off Bic Island as shown on Figure 3.1. The manoeuvering trials were also extended into Davis Strait for the reasons explained later, and the combined schedule was as follows,

Table 3.1 - Open water trials

TIME PERIOD		Trial	Location
From	To		
250800	251400	Speed/Power	Les Escoumins
251700	251915	Turning Circles	Off Bic Island
251915	251930	Crash Stop	" " "
251930	252000	Z Manoeuvers	" " "
252000	252120	Dir. Stability	" " "
290930	291040	Dir. Stability	Davis Strait
291100	291140	Z Manoeuvers	" "

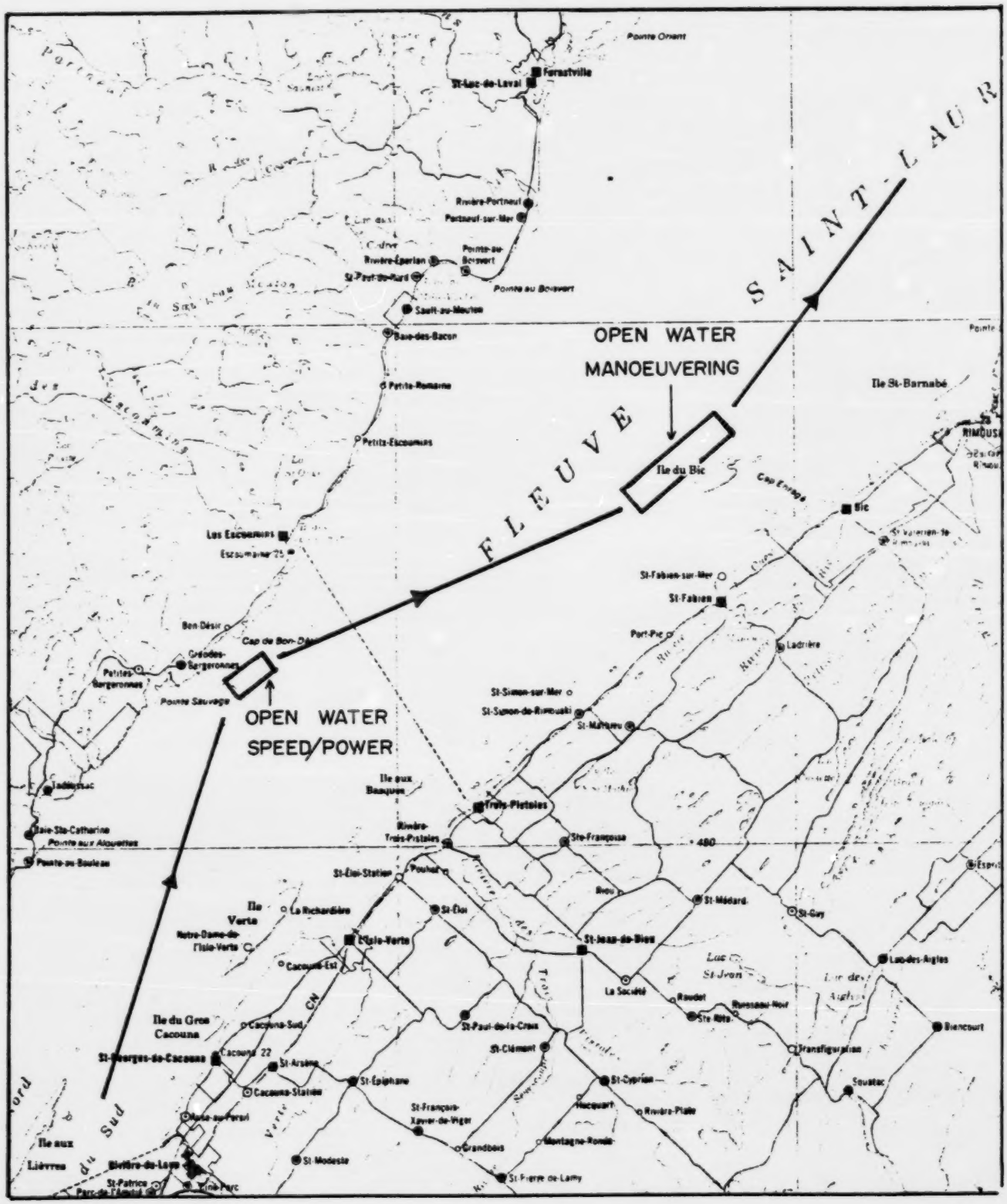
Nine speed/power runs were performed on the measured mile, four double runs at powers from 60% to 100% with one extra run at 100% power. After allowance for wind and wave effects, the full power speed showed a small improvement against the old bow, as was predicted from the comparative model tests.

The manoeuvering trials commenced with the turning circle test, one each to port and starboard for 540° in both cases. Each test commenced with the ship's head to wind and sea to balance those effects. The turning diameter was about five ship's lengths each way. Similar to the results with the previous bow .

During the crash stop from full ahead, the ship pulled up in about five ship's lengths and turned about 130° to starboard. These results were similar to those of the previous bow.

The 'Z' manoeuvers were conducted at 20° and 35° helm followed by the directional stability tests firstly under helm control and then with helm fixed. The wind and wave conditions were not considered to be ideal for these tests coupled with the fact that when the bridge helm indicator showed midships, the rudder was actually 3° to starboard. For these reasons, it

Figure 3.1 - Open Water Trials



was decided to repeat the 'Z' manoeuvers and directional stability tests at a suitable calm weather opportunity.

This opportunity occured on May 29, 1986 in Davis Strait when both tests were performed under ideal weather conditions. The 'Z' manoeuvers resulted in yaw angle overshoots of about 50% of the rudder angle. The directional tests revealed exceptional straight line stability for a period of ten minutes. This completed the open water trial program the results of which, speed and manoeuverability were highly satisfactory.

4. BAFFIN BAY TRIALS

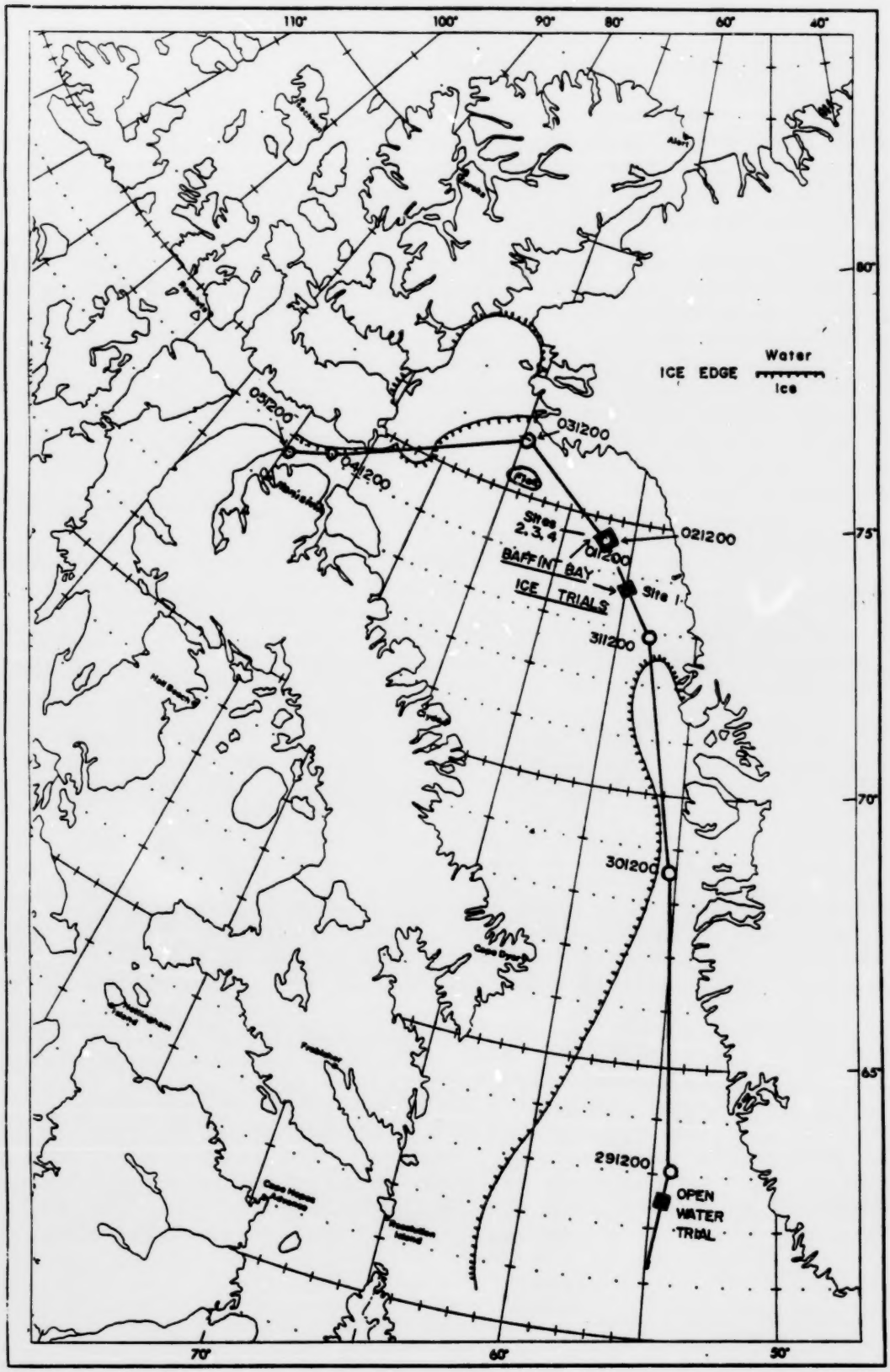
The M.V. Arctic proceeded from the St Lawrence River passing north of Anticosti Island, cleared the Strait of Belle Isle by noon on May 27, 1986 (271200) and headed northwards to enter Davis Strait in the early morning of May 29, 1986. The vessel's course from noon that day (291200) to the entrance of Admiralty Inlet (051200) is shown on Figure 4.1 together with the position of supplementary open water manoeuvering trial referred to in Section 3 and the four sites of the Baffin Bay ice trials. The figure also shows the location of the ice edge in this area, The ice trials schedule was as follows.

Table 4.1 - Baffin Bay trials

TIME PERIOD		Site	Test	Comments
From	To			
311800	311900	1	Speed/Power in ice	Light ice
010900	011130	2	Speed/Power in ice	Medium ice
011130	011330	"	Reversing	+ Ice data
011330	011530	"	Channel Breakout (3,S)	
011530	011930	"	Broken Channel speeds	+ Ice data
011930	012330	"	Reversing	+ Ice data
012330	020030	"	Channel Breakout (2.P)	
020700	020800	3	Speed/Power in ice	Medium ice
020800	020930	"	Reversing	+ Ice data
020930	021230	"	Broken Channel Speeds	+ Ice data
021230	021300	"	Turning circle (P)	Aborted
021530	021545	4	Turning circle (S)	Aborted
021615	021630	"	Channel breakout (1.P)	
021630	021645	"	Direct Stability	
021645	021700	"	Inertial Stop	End of Tests.

During the northward voyage, on May 30, 1986, a meeting was held between the trials team and the ship's officers to explain the test program. The main trials location was identified from the satellite imagery as a major floe in western Melville Bay as shown in Figure 4.1. Final choice of site would be determined however, from the SLAR over flights to be conducted on May 31, and June 2, 1986. A site for a lighter ice test, less than 1 metre thickness, would also be used if a suitable opportunity arose. This latter is shown as site 1 on Figure 4.1.. The main tests were carried out at sites 2,3 and 4 which were in close proximity to each other and selected through the SLAR imagery. The major floe was not used due to its distant location and to the difficulty of identifying

Figure 4.1 - Baffin Bay Route & Trial Sites



its precise nature. The problem of imagery interpretation is further discussed in Section 6 of this report.

Site 1 was identified visually from the ship and was a small level floe sufficient to provide one data point at full power speed. Ice data was collected at this point. An attempt was made to use this site also for a turning circle but had to be abandoned due to fracturing of the floe.

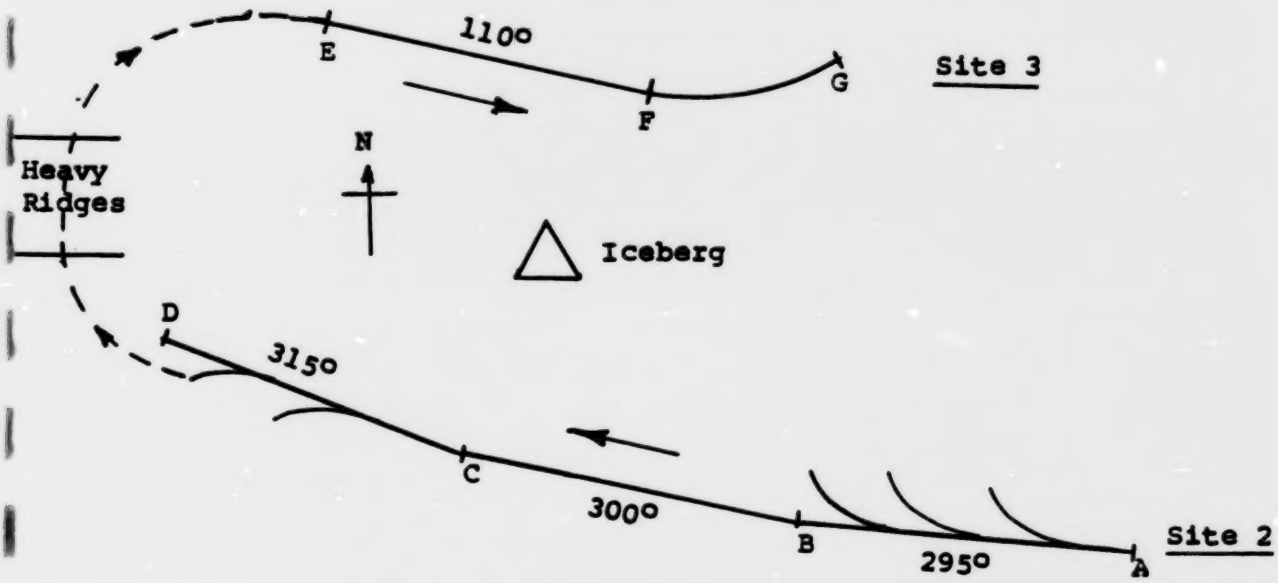
The main tests were conducted in Sites 2 and 3 and commenced in the morning of June 1, 1986. Due to the limited expanse of smooth ice found to be suitable for testing, the program was highly concentrated and integrated into the available area. This is best explained by the diagram provided in Figure 4.2.. It will be noticed that Site 2 tests could not be conducted in a single straight line but instead a path of three legs each about 1 mile in length, was adopted to utilise the best ice conditions. Good speed in ice, broken channel and channel breakout tests were conducted in Site 2 together with ice data measurements. The drafts were verified. Particular difficulty was found in backing and canting the vessel into the main channel after each channel breakout test. Based on this time consuming experience, it was agreed that channel breakouts would be reduced from five to three each way with a change of heading reduced from 45^{o} to 25^{o} . The vessel was extremely effective in performing the actual breakout but not in reversing back into the channel.

The vessel was moved from Site 2 to Site 3 a short distance away to continue the main trials. The passage between these two sites required the vessel to traverse a region of heavy ridging,rafting and rubble, which was negotiated with great difficulty. The vessel became stuck several times and was extracted only with great difficulty after each ram.

The speed/power tests were completed at Site 3 and the turning circle trials commenced. The vessel was turned to port under full rudder but could manage only a 20^{o} change of heading. This test was aborted and a new site sought.

A floe with moderately uniform ice was found in the afternoon of June 2, 1986 and adopted as Site 4. The turning circle test was attempted to starboard but was again aborted after only a 20^{o} change of heading could be achieved. It became evident that the M.V. Arctic had little turning ability in ice above about 1 metre in thickness. All such turns would require a series of breakout manoeuvers. The main program was completed at Site 4 with the remaining channel breakout to port, the directional stability tests and an inertial stop.

Figure 4.2 - Trials sequence at sites 2 & 3



SEQUENCE AT SITE 2	
Enter	A to B
Speed/Power in ice	B to D
Reverse	D to A
Wait ice party	A
Channel breakouts (3. stbd)	A to B
Broken channel speeds	B to D
Reverse	D to B
Wait ice party	B
Broken channel speeds	B to D
Wait ice party	D
Reverse	D to C
Wait ice party	C
Channel breakouts (2. port)	C to D
Proceed to E	

SEQUENCE AT SITE 3	
Speed/Power in ice	E to F
Reverse	F to E
Wait ice party	E
Broken channel speeds	E to F
Wait ice party	F
Turning circle (port) Proceeded	F to G

The program was completed by 021700 and the vessel proceeded towards Cape York and thence to Admiralty Inlet.

The Baffin Bay trials program was successfully completed except for the turning test. The weather was fine throughout with only light winds and no noticeable ice pressure at the test sites. Under adverse weather conditions coupled with the difficulty of finding suitable expanses of uniform ice, it is doubtful whether Baffin Bay could be a good choice of trial location.

5. ADMIRALTY INLET TRIALS

Prior to arrival off Admiralty Inlet a meeting was held between the trials team and the ship's officers to explain the test program. The M.V. Arctic reached the edge of the Shear Zone at the entrance to Admiralty Inlet on June 4, 1986 at 1700 hours ship's time (041700). The passage down Admiralty Inlet, into Strathcona Sound was completed when the vessel was berthed alongside Nanisivik wharf on June 8, 1986 at 2400 hours ship's time (082400). The route taken with positions every twelve hours and, the test locations are shown on Figure 5.1 with an overlay of the ice profile.

The total distance of 60 miles from arrival at the edge of the Shear Zone off Admiralty Inlet to berthing at Nanisivik dock was traversed in 96 hours (excluding 7 hours attributable to the trials program) at an average speed of 0.6 knots. The various sectors of this passage are listed in the following table showing the average speed attained in each sector which can be identified on Figure 5.1.

Table 5.1 ADMIRALTY INLET - PASSAGE SUMMARY

TIME SECTOR	HOURS			DISTANCE SEAMILES	AV.Spd Knots	COMMENT
	TOTAL	TRIALS	NET			
041700-042400	7.0	-	7.0	5	0.7	Shear Zone
042400-050400	4.0	-	4.0	1	0.2	Turn 40 Port
050400-051200	8.0	1.5	6.5	3	0.5	Ramming
051200-052400	12.0	2.2	9.8	7	0.7	"
052400-061200	12.0	1.3	10.7	3	0.3	"
061200-062400	12.0	2.0	10.0	10	1.0	Some Cont.
062400-071200	12.0	-	12.0	8	0.7	Ramming+Turn
071200-072400	12.0	-	12.0	6	0.5	" +Turn
072400-081200	12.0	-	12.0	13	1.1	Some Cont.
081200-082400	12.0	-	12.0	4	0.2	Turn and dock
TOTALS	103.0	7.0	96.0	60	0.6	

Progression throughout this passage was predominantly by ramming with some intermittent short periods of continuous motion where the ice thickness was less than about 1.6 metres. All turns had to be executed as channel breakout manoeuvers as the ice was too thick for the ship to turn by the action of the rudder alone. The weather throughout was fine and clear with only light following winds and the absence of ice pressure. Accordingly, it can be concluded that the above passage time and average speeds are the best attainable for the ice conditions encountered.

Figure 5.1 - Admiralty Inlet Ice Profile

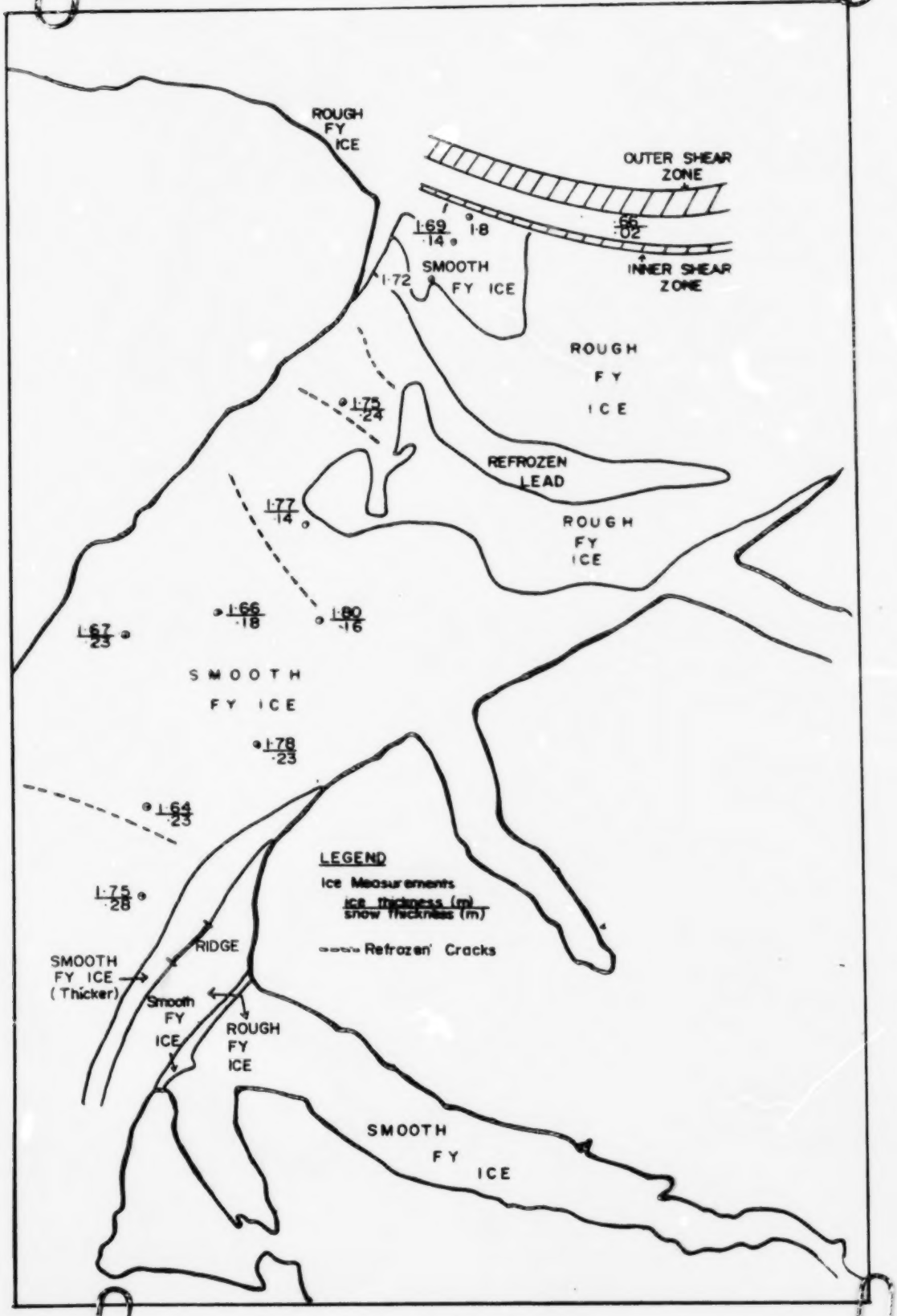
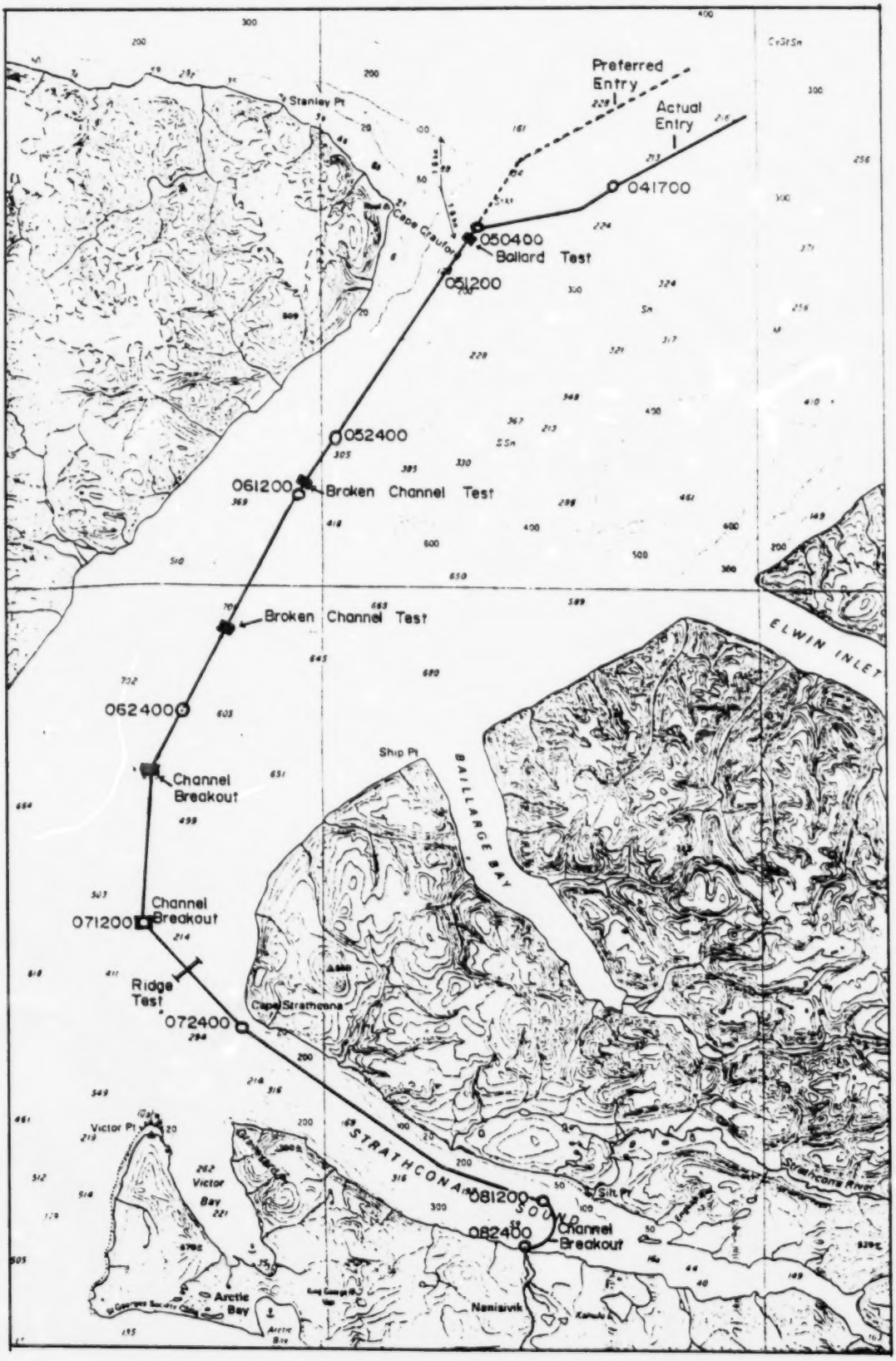


Figure 5.1 - Admiralty Inlet Route

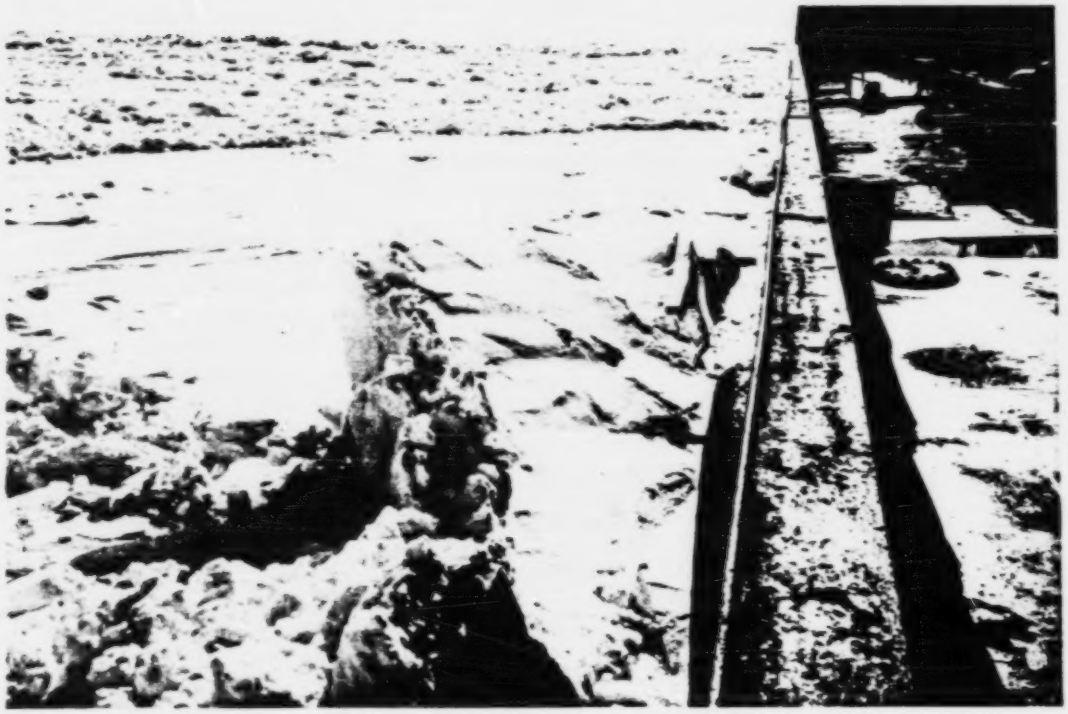


The Shear Zone comprised two distinct regions, an outer mobile region about one mile in width with ice up to 3 metres thickness, separated by a two mile wide area of level fast ice, of less than 1 metre thickness, from the inner static shear region which was about one tenth mile wide with ice up to 2 metres thickness. The outer shear region presented the most difficult ice conditions of the whole voyage, taking almost 5 hours (041700-042200) to penetrate its one mile width. An impression of the ice conditions encountered is provided in Figure 5.2. Particular ramming difficulty was encountered due to the fact that the channel astern of the vessel was continually congested with major ice pieces which limited backing to about ¼ ship's length. Due to this space restriction only low ramming impact speeds could be developed and, thus, the penetration distances were small for each ram. After having penetrated the outer shear region, the vessel traversed the intermediate expanse of level ice and the inner shear region in two hours (042200-042400) without difficulty. At this point a 40° turn to port had to be made to attain the required course down Admiralty Inlet. This turn took four hours (042400-050400) to execute in 1.8m thick ice and required 15 channel breakout manoeuvers in addition to heeling the vessel 3° to port and full use of the bubbler.

After only about two miles on the new course, at 050700, a further heavy ridge was encountered which presented a type of difficulty which differed from that reported above for the shear zone. In this case, extraction after ramming was the problem due to the resistance caused by the close packing of the ice along the length of the ship. The bubbler was again activated but was unable to force air through the nozzles which were blocked by ice. Each pitch reversal using full power produced a ship movement of only about five feet. This was eventually sufficient to ease the ice pressure and permit a bubbler flow, the lubricating effect of which gradually increased the vessel's movement until extraction could be achieved. Further rams were cautiously conducted with less penetration so that there was less extraction difficulty. It took nearly an hour to traverse this ridge which was less than one ship's length in width. The vessel appears to be underpowered to deal with this extreme kind of extraction difficulty and the bubbler's contribution was invaluable.

It is evident that careful planning is needed to achieve the best strategy for traversing the shear zone and the neighbouring area. On this occasion, the preferred route is shown on Figure 5.1 with an entry course of about 215° true along the line of the track down Admiralty Inlet. This not only avoids the time consuming turn referred to earlier but also provides an easier route through the outer shear region.

Figure 5.2 - Admiralty Inlet Outer Shear Region



General View

Bow Impression

The preferred route was identified by the ice party but they were unable to transmit this information to the ship due to poor radio communications. The best ice conditions appear to be found on the Cape Crauford side of the entrance to Admiralty Inlet. In order to take full advantage of this, entry route planning should be an essential feature of the first voyage each year and conducted prior to the ship's arrival off the Shear Zone. SAR imagery would be adequate for overall route planning throughout Admiralty Inlet which should seek the best comprise between the ice thickness profile and the minimisation of turns. For the first 10 miles, however, there is no substitute for expert on-ice visual inspection which would require the use of a helicopter.

Four major turns as shown on figure 5.1 were conducted during the passage, each performed as a series of channel breakout manoeuvers. The details are as follows.

Table 5.2 ADMIRALTY INLET - SUMMARY OF TURNS

Time Period			Angle turned	Degrees per hour	Ice thickness
From	to	hours			
042400	050400	4.0	40° (P)	10°	1.80
070200	070400	2.0	20° (P)	10°	1.70
071200	071500	3.0	50° (P)	17°	1.65
081200	081800	6.0	180° (S)	30°	1.55

The rate of turn improved with decreasing thickness of ice but the main improvement was undoubtedly attributable to perfecting the channel breakout technique. This required that the channel be broken in such a way that there was always room for the stern to swing away from the direction of turn. The development of the tactics required to continually break the ice on the opposite side of the channel immediately improved the turning capability of the ship. Without such tactics, the M.V. Arctic would not seem to be able to execute a turn greater than about five degrees. In the short term, continued opportunities should be taken to perfect the technique and in the longer term future design should examine stern shape and quarter flare to improve the effectiveness of the stern during turns and for reversing.

A series of 210 performance tests were recorded during the Admiralty Inlet and Strathcona Sound passage as summarised in the following table.

Table 5.3 ADMIRALTY INLET SUMMARY OF TRIALS

Time Period		Type of Test	No of Records
From	To		
041700	042100	Ramming (Outer Shear)	22
042200	042400	Ramming (Inner Shear)	5
042400	050400	Channel turn	2
050400	050430	Bollard	5
050430	061000	Ramming (Level ice)	95
061200	070200	Broken Channel Speed	3
"	"	Ramming (Level ice)	17
"	"	Continuous (Level ice)	6
070200	070400	Channel turn	7
071600	071700	Ramming (Ridge)	5
071700	080100	Ramming (Level ice)	33
080600	081000	Continuous (Level ice)	3
081200	081800	Channel turn	7
TOTAL			210

In support of these records, ice measurements including thickness and strength were taken at appropriate positions along the route for input into the detailed performance analysis. Excluding the shear zone, ice thickness varied between about 1.8 and 1.5 metres. The vessel could maintain slow continuous motion in the lesser ice thickness.

The last major obstacle to be overcome was the ridge across the entrance to Strathcona Sound. This was breached in a single ram at an impact speed of about 6 knots and the vessel continued beyond the ridge for about two ship lengths before stopping. The remainder of the voyage along Strathcona Sound involved intermittent ramming and continuous motion.

This successful passage and indeed the whole successful voyage was convincingly completed by the M.V. Arctic berthing at Nanisivik wharf without assistance. The docking operation was concluded as a series of manoeuvers in which the fast ice and bolsters at the caissons were firstly dislodged by the bow and shoulder as the vessel passed and then the ice pieces were washed away by the propeller race. This process took about 6 hours (081800-082400) until the ship was made fast port side to the dock. In this position her departure would only involve new icebreaking for about three miles in order to rejoin the inward broken channel. Thereafter it is expected that continuous mode progression would be made to clear Admiralty Inlet outward bound.

6. INSTRUMENTATION SYSTEMS

The instrumentation used aboard the vessel during the Spring 1986 performance trials comprised two systems as follows;

- Ship performance data acquisition system
- Ice reconnaissance imagery system.

Each of these systems are described below.

6.1 Ship performance system

The ship performance instrumentation system consisted of a permanent and temporary installation as shown in Figure 6.1. The permanent installation has a capacity of 256 sensor channels with each sensor connected directly back (star configuration) to the signal conditioning and amplifier unit located in the ship's laboratory. Each channel is recorded digitally at the uniform rate of 100 samples per second with the system capability of monitoring a reduced number of channels at higher rates up to the ultimate capacity of 25,600 samples per second.

System control is exercised through the main computer and multi-programmer located in the laboratory. The signals are converted into engineering units and the outputs diplayed as tabulations, time series plots or histograms on the monitor or printed in hardcopy. A similar output capability is available on the bridge which is inter-connected with the laboratory installation through the bus extensor. The bridge installation also includes a colour monitor for special displays, related to hull girder bending stresses, located at the conning position.

Approximately 70 channels of the total 256 channels are occupied at present. These are listed in Table 6.1 and comprise sensor groups for; propulsion and steering, ship course and speed, bow and bridge accelerations, hull girder deck bending stresses, shell frame and stringer stresses at the stern. The table also details the location of each sensor in terms of its distances from the aft perpendicular (Frame 0), off the centre-line and above the keel.

The permanent system collects, processes and provides the minimum, mean and maximum values of each sensor every 1.5 seconds Four such data intervals are continuously stored and updated on a moving interval basis. An alarm level is set on each sensor and when this is exceeded on any sensor the system

FIGURE -6.1

LAYOUT OF DATA
STORAGE AND ANALYSIS HARDWARE

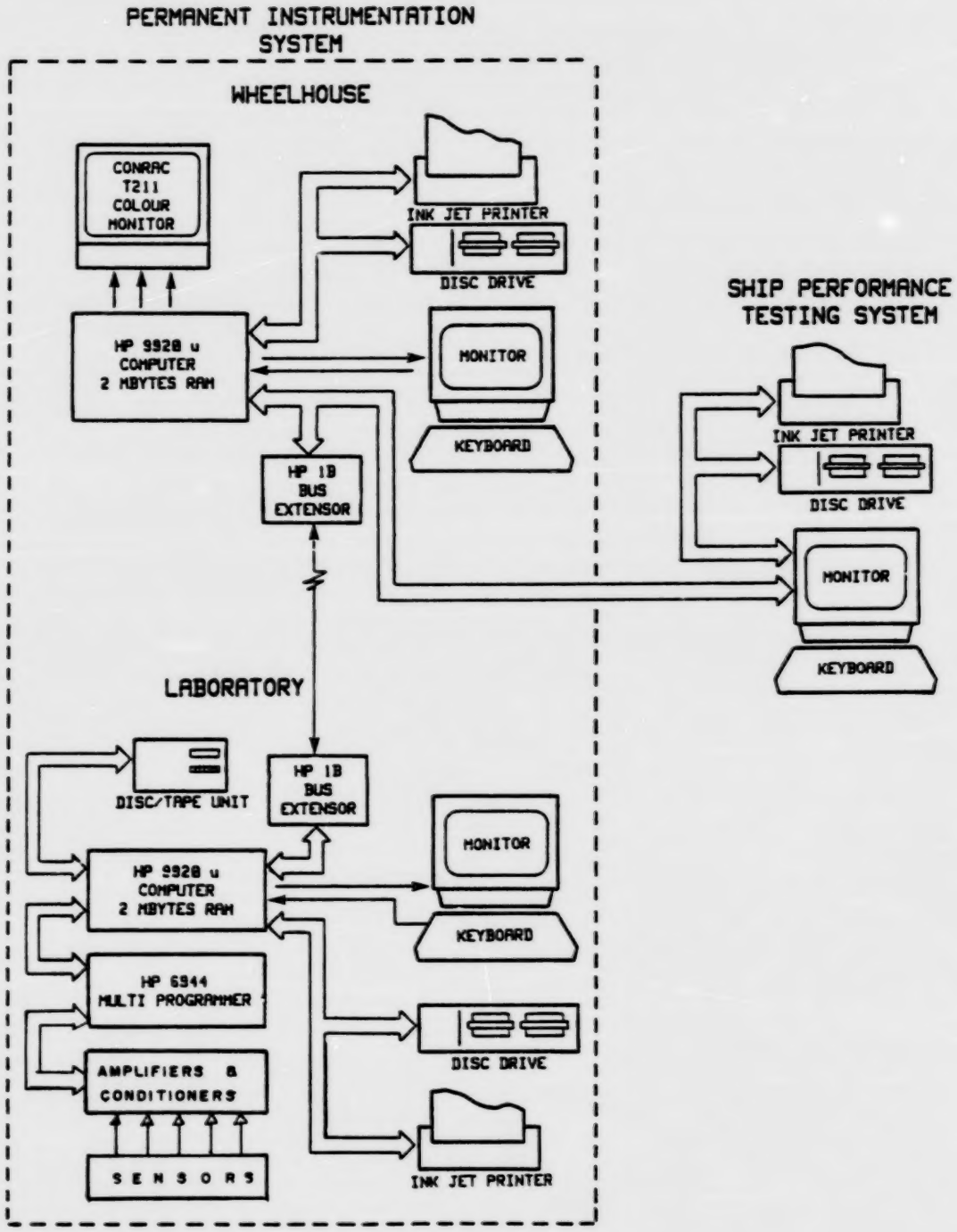


Table 6.1 - Sensor Locations

NO.	SENSOR	LONG (feet)	TRANS (feet)	VERT (feet)	FRAME
1	TORQUE	54.00	0.00	15.00	27.00
2	THRUST	65.00	0.00	15.00	32.50
3	RPM	55.00	0.00	15.00	27.50
4	PITCH	51.00	1.00	18.00	25.50
5	RACK	94.00	-4.00	23.50	47.00
6	RUD ANG	2.00	1.50	44.00	1.00
7	OW LOG	521.00	1.00	0.00	160.25
8	PRESS	8.00	7.50	42.00	4.00
9	COMBIN	97.50	-1.25	89.50	48.75
10	BRGE X	97.50	-1.25	89.50	48.75
11	BRGE Y	98.50	5.00	87.50	49.25
12	BRGE Z	98.50	5.00	87.50	49.25
13	HDG SIN	88.50	6.75	89.00	44.25
14	HDG COS	88.50	6.75	89.00	44.25
15	BOW Y	672.00	0.00	51.50	218.00
16	BOW Z	672.00	0.00	51.50	218.00
17	DB112S	331.00	-21.00	50.25	112.75
18	DB112P	331.00	21.00	50.25	112.75
19	DB120S	362.00	-24.00	50.25	120.50
20	DB142S	450.00	-24.00	50.25	142.50
21	DB163S	533.00	-21.00	50.25	163.25
22	DB163P	533.00	21.00	50.25	163.25
23	DB170S	562.00	-24.00	50.25	170.50
24	DB174S	578.00	-24.00	50.25	174.50
25	DB180S	597.00	-26.25	50.40	180.50
26	DB180P	597.00	26.25	50.40	180.50
27	DB198C	632.50	0.00	61.50	198.25
28	DB208C	652.00	0.00	62.00	208.00
29	DB216C	668.00	0.00	62.50	216.00
30	DB224C	683.00	0.00	63.00	223.50
31	ICE LOG	79.50	32.00	86.00	39.75
32	RUD TOR	0.00	0.00	39.50	0.00
33	FB13	26.00	17.00	36.25	13.00
34	SB16	32.00	15.00	32.75	16.00
35	FB16	32.00	18.75	36.25	16.00
36	SB18	36.00	16.30	32.75	18.00
37	FB18	36.00	19.90	36.25	18.00
38	SB20	40.00	17.70	32.75	20.00
39	FB20	40.00	21.00	36.25	20.00
40	SB22	44.00	18.90	32.75	22.00
41	FB22	44.00	22.20	36.25	22.00
42	SB24	48.00	20.25	32.75	24.00
43	FB24	48.00	23.25	36.25	24.00
44	SB26	52.00	21.50	32.75	26.00
45	FB26	52.00	24.20	36.25	26.00
46	SB28	56.00	22.50	32.75	28.00
47	FB28	56.00	25.25	36.25	28.00
48	SB30	60.00	23.50	32.75	30.00
49	FB30	60.00	26.10	36.25	30.00
50	SB32	64.00	24.60	32.75	32.00
51	FB32	64.00	27.00	36.25	32.00
52	SB34	68.00	25.60	32.75	34.00
53	FB34	68.00	27.80	36.25	34.00
54	SB36	72.00	26.60	32.75	36.00
55	FB36	72.00	28.70	36.25	36.00
56	CHANNEL56	0.00	0.00	0.00	0.00
57	FB38	76.00	29.50	36.25	38.00
58	CHANNEL58	0.00	0.00	0.00	0.00
59	FB40T	80.00	30.10	36.25	40.00
60	FB42B	84.00	28.60	32.00	42.00
61	FB42T	84.00	30.00	36.25	42.00
62	FB44B	88.00	29.40	32.00	44.00
63	FB44T	88.00	31.50	36.25	44.00
64	FB46B	92.00	30.00	32.00	46.00
65	FB46T	92.00	32.00	36.25	46.00
66	FB48B	96.00	30.70	32.00	48.00
67	FB48T	96.00	32.50	36.25	48.00
68	FB50B	100.00	31.40	32.00	50.00
69	CHANNEL69	0.00	0.00	0.00	0.00
70	FB40B	80.00	27.80	32.00	40.00
71	FB50T	100.00	33.00	36.25	50.00

DB = Deck Bending
FB = Frame Bending
SB = Stringer Bending

captures and stores the data on all sensors for that 1.5 second interval, together with the preceeding interval and the succeeding four intervals, a total period of 9 seconds. All such alarms events are permanently stored and can be retrieved individually or cumulatively as tables, plots and histograms. It was noted that during all numerous ramming, backing and canting operations carried out in heavy ice during this trial program, no alarm limits were exceeded on hull girder and stern frame bending. There were many occasions, however, of high excusions (some with alarms) of thrust and torque due to ice ingestion in the propeller, three times more frequently astern than ahead. Rudder torque alarmed on one occasion whilst reversing.

The temporary ship performance testing system is also located on the bridge and is inter-connected with the permanent system as shown in Figure 6.1. Special software developed for the spring trials program accumulates the 1.5 second interval data from the permanent system and develops, for the selected sensors, the cumulative minimum, mean and maximum values for the duration of each test. The software also provides a variety of graphical results some examples of which are provided in Figure 6.2.

This system has operated excellently throughout the trial program and has provided clear summaries and graphics within minutes of the completion of each test. This has permitted an immediate assessment to be made of the test results and thus has proved to be an important trials management tool for signaling when a test can be accepted or should be repeated.

The system was also found to have the further advantage of providing the ship's engineers with the information needed for tuning the propulsion system. This required frequent instantaneous information on pitch, torque, revolutions and shaft power so that power setting could be accomplished in association with the engine governor and fuel rack.

It was evident from the experience gained on this voyage that the performance testing system should be incorporated into the permanent installation for use both on the bridge and in the engineroom.

Figure 6.2 - Sample of test record

RUN: 14 — M.V. ARCTIC — 25 May 1986
DISK: 4 — 1986 SPRING SHIP PERFORMANCE TRIAL — 19:29:47
TEST: 4 . 1 — O.W. CRASH STOP TEST — 199 REC

START: 19:24:49
STOP: 19:29:49

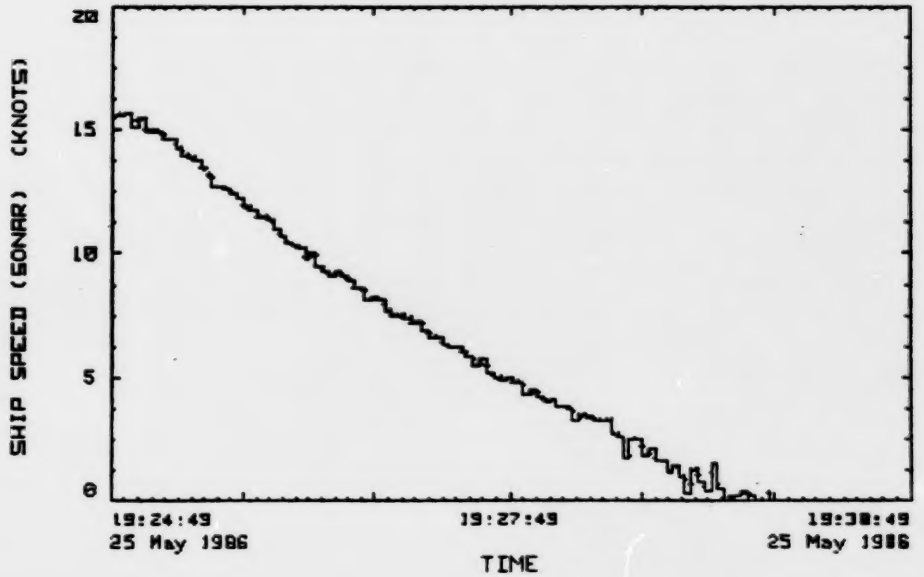
	MIN	MAX	MEAN
COMBINATOR POSITION	-10.06	9.98	-9.95
SHIP SPEED (SONAR) KNOTS	-.11	15.70	7.06
SHAFT THRUST kN	-95.46	1421.64	660.02
SHAFT TORQUE kNm	26.72	1459.74	711.78
SHAFT SPEED RPM	117.41	145.41	135.69
PROP PITCH DEG	-14.78	22.85	-11.73
RUDDER TORQUE kNm	-490.50	209.50	-109.65
CHANGE OF HEADING DEG	0.00	129.60	60.27

ELAPSE TIME (min) : 4.975
< SONAR SPEED LOG >
INITIAL SPEED (KNOT) : 15.52
FINAL SPEED (KNOT) : .32
TRANSIT DISTANCE (km) : 1.084

INITIAL SHIP HEADING (DEG) : 62.18
FINAL SHIP HEADING (DEG) : 191.78

RUN 14 TEST 4.1 O.W. CRASH STOP

CH 7 SHIP SPEED (SONAR) PAGE:1/1



6.2 Ice reconnaissance imagery system

The ice imagery installation aboard the M.V. Arctic consisted of two systems namely satellite optical-observed and aircraft radar-observed imagery. Both systems are basically similar whereby the optical or radar imagery is transmitted by radio from the observing vehicle to the downlink receiver on the ship. The signal is processed and formatted under computer control and stored on hard disc or tape. The stored information can be subsequently retrieved and displayed on a CRT screen. In the case of the aircraft system, the imagery can also be produced on film by a fibre-optic printer. The film can then be projected onto a display table with zoom capability for matching a navigation chart.

Aircraft imagery can be based upon either sideways looking airborne radar (SLAR) or synthetic aperture radar (SAR), the latter provides higher definition imagery. Only the SLAR system was available for the ship trials voyage.

The satellite and aircraft systems complement each other with the former identifying the main concentrations of ice and the latter providing more detailed information on the floe regime. In both cases, however, there appears to be some difficulty in pinpointing the precise position of ice features which could be improved through the incorporation of a geographical grid. The picture quality is also an important consideration and, for example, the satellite imagery seems to be highly sensitive to open water so that open water was indicated in areas where there was 5/10ths of ice coverage. The icefax transmitted from ice central provided an accurate picture of the actual ice conditions experienced but shipboard receptien was poor.

The satellite and SLAR imagery obtained during the voyage were indisputably essential for routing and helpful in identifying possible trial locations at the north end of Baffin Bay. Ship performance trials of this precise nature, however, require some rather special ice conditions in terms of uniformity of surface and thickness over an area not less than 5 miles diameter. Even with the higher resolution of SAR such requirements may still be too difficult to detect from imagery. A third system seems to be necessary such as a helicopter for close visual observation for final site selection.

It must be recognised that due to the overall dynamics of currents and winds, Baffin Bay may offer little in the way of good ice trial conditions. The landfast coastal, fjord and inlet ice may be more suitable. On the Greenland side however, there would be problems due to entry into Danish waters, poor hydrography and iceberge interference. Whilst on the Canadian side heavy pack ice may make access to suitable inlets impossible.

7. SUMMARY OF FINDINGS

Based upon the various matters addressed in the previous sections of this report, the following summary of findings is provided.

7.1 Overall Voyage

The voyage from Montreal to Nanisivik, including the trials, was completed in 15½ days as follows,

	Hours	Seamiles
Normal passage	318	2816
Performance trials	55	184
Total	373	3000

The average daily speed varied from about 16 knots in open water to about ½ knot in the heaviest ice. The voyage, including docking at Nanisivik, was completed successfully by the M.V. Arctic without assistance.

7.2 Open Water Trials

The open water trials were conducted primarily in the vicinity of Les Escoumins and Bic Island and were completed in Davis Strait, with the following results,

- The full power speed achieved was slightly greater than with the old bow as was predicted by the model tests.

- The turning circle, zigzag manoeuver and directional stability results continued to be as good as with the old bow.

7.3 Ice Trials

The ice trials were conducted in Baffin Bay and Admiralty Inlet with the following results,

- Continuous motion at full power was maintained in non-pressured ice up to about 1.6 metres thick and confirmed the most optimistic of the model test predictions.

- Broken channel speeds up to 12 knots were achieved in 100% coverage of ice pieces of about 1 metre in thickness.

- Continuous turning under the action of the rudder alone cannot be achieved in ice above about 1 metre in thickness. In thicker ice, sizeable course alterations have to be performed as a series of channel breakout manoeuvers conducted in such a manner as always to provide sufficient space for the stern to swing outwards.

- Channel breakouts appear to be more effective than with the old bow in comparable ice thicknesses. After such a manoeuver, however, the vessel has great difficulty in canting astern back into the original channel.

- Ramming capability of the ship was sufficient to overcome all the heavier ice conditions encountered during the voyage. There were, however, two noteworthy incidences in which the vessel became stuck after ramming a ridge and was extracted only with great difficulty. This suggests that the power requirements (ahead and astern) for arctic vessels should give recognition to the icebreaking effectiveness of the bow.

- Icebreaking cusp size diminished as the thickness of the ice increased. In ice about 2 metres thick, the cusps were hardly visible and, consequently, the ice remained in close contact with the hull along the length of the ship. This explains, in part, some of the extraction difficulties noted above.

- The shear zone at the entrance to Admiralty Inlet presents a considerable obstacle. A strategic plan for the best approach and crossing of the shear zone is required for the first entry voyage each year and should be based upon on-ice visual observations prior to the ship's arrival.

- Ice conditions in Baffin Bay and in Admiralty Inlet, inside the shear zone, presented no significant difficulties to the M.V. Arctic on this voyage. It must be noted, however, that the voyage was conducted in exceptionally fine weather with only light winds. The effect of adverse weather, high winds and ice pressure potential would have to be taken into account in route planning and passage time estimating in other years.

- The ice regime in Baffin Bay is generally unsuited to ice trials of this precise nature where a large expanse, at least five miles in diameter, of smooth uniform ice is required. The general current and wind dynamics of Baffin Bay make this difficult to find.

- Docking unassisted at Nanisivik provided a convincing conclusion to a successful voyage. The total process took about twelve hours starting with six hours to turn the vesselround 180° from the inward track along Strathcona Sound. The remaining six hours were needed to break and clear the ice bolsters at the caissons and dock the vessel. In this position, the vessel was ready for the outward journey requiring only a short distance of new icebreaking in order to regain the inward broken channel.

7.4 Shipboard Instrumentation

Two instrumentaion systems (performance recording and ice imagery) were installed aboard the vessel and used for the trials with the following results,

- A temporary performance recording system, including trials software, was installed and linked into the vessel's permanent hull sensing system. The temporary system proved to have three valuable uses,

  1. Test recording with instantaneous playback of results in numerical and graphical forms.

  2. Trials management using the above outputs to assess the acceptance or rejection of each test result immediately as it occurred.

  3. Provision of instantaneous data to the ship's engineers to permit accurate power setting of the main engine and combinator control.

  The above experience would justify incorporation of this test system into the ship's permanent installation for use by the ship's officers on the bridge and in the engineroom. In this way, a continuum of performance information could be obtained on a voyage basis including onboard data to guide the perfecting of ramming and turning tactics developed by the officers.

  The system also revealed that no alarm exceedences occurred on hull girder and stern frame bending stresses during ramming but there were frequent high excursions of ice-related thrust and torque.

- An ice imagery installation consisting of two complementary systems, one being satellite and the other aicraft based. The following comments are made.

  1. The satellite imagery provides an excellent overview of the ice conditions over a large area but tends to over-emphasise the amount of open water present. The present satellites do not have all-weather capabilities and, thus, this ice imagery could not be obtained under heavy overcast cloud conditions.

  2. The aircraft imagery provides a more detailed localised ice imagery for route planning, with SAR offering better resolution than SLAR. The absence of a geographical reference grid on the present systems complicates the precise positioning of the aircraft imagery on a navigation chart.

  These two systems whilst being invaluable for normal route planning through icefields cannot provide the degree of ice detail needed for identifying precise conditions such as are required for ship trials. For this purpose, a third system is needed using a helicopter for close and on-ice visual observations of a number of options and selection of the best.

This completes the main findings arising from this voyage and leads to certain recommendations.

8. RECOMMENDATIONS

Based upon the principal findings of this voyage and trials, IT IS RECOMMENDED THAT:

8.1 A further program of ice trials should be conducted at the end of the ship's arctic season to assess her effectiveness in an advanced winter growth ice regime subject to corresponding composition, strength and dynamic conditions.

8.2 Every opportunity should be taken by the ship's officers to perfect the channel breakout manoeuver as the tactic used for effecting large course alterations in thick ice.

8.3 An investigation should be made of stern shape and quarter flare for use in future designs for improving the sternwards ice-breaking and canting effectiveness of long vessels such as the M.V. Arctic.

8.4 An investigation should be made to determine the relationship between icebreaking bow effectiveness and power requirements to reduce the present risk of long and high momentum vessels becoming stuck after a ram and being difficult to extract.

8.5 An investigation should be made to determine whether the better downward breaking capability of the new bow has resulted in a greater number of ice pieces being forced under the hull and ingested into the propellor.

8.6 The temporary performance recording system used for these trials should be incorporated into the vessel's permanent instrumentation system for use by the ship's officers on the bridge and in the engineroom.

This completes the recommendations arising from this voyage.

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